Pre-Ph.D. Registration Synopsis

Assessment of karyomorphological, morphological, biochemical and phytoremediation potential of *Capsicum* species under Arsenic stress

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STATE OF THE ART

The herbaceous flowering plant genus *Capsicum* species is a member of the Solanaceae, a large family of tropical and subtropical plants, and includes both self-pollinated and cross-pollinated species[1,2]. The majority of *Capsicum* are diploid in nature and have 24 chromosomes (n=12), however some wild species have 26 chromosomes (n=13). The only tetraploid is *C. annuum* var. *glabriusculum* (4n=48)[3]. It is a dicotyledonous shrub that grows annually and perennially, with a limited lifespan[4]. It produces berries, with morphological variations in fruit size, length and number per plant, seeds per fruit, fruit colour and fruit stalks[5,6]. These fruits go through substantial morphological, physiological, and metabolic changes as they ripen. Chilli is rich in pigments such as chlorophyll (green), anthocyanins (violet/purple), α- and β-carotene, zeaxanthin, lutein and β-cryptoxanthin (yellow/orange), which contribute to its vibrant colours[7]. It is commonly referred to as capsicum in Australian and Indian English, although in Britain it is also known as chilli pepper, red or green pepper or sweet pepper. The large, mild version is called bell pepper in Canada and the US and paprika in certain other areas. The Centre of origin for *Capsicum* is regarded as Central or South America and was first cultivated in Mexico[7]. The Portuguese brought *capsicum* to India in the fifteenth century[8]. India, Bangladesh, Pakistan, Ethiopia, China and Thailand are the leading chilli producers. India accounts for 43% of global chilli production, making it the world's top producer, according to the FAO India produced 1.98 million metric tons of chillies in 2023–2024[9]. Karnataka, Odisha, Madhya Pradesh, Telangana, and Andhra Pradesh are among the Indian states that produce chillies[10]. The largest area in the nation dedicated to chilli growing is found in the state of Andhra Pradesh[11]. A greenhouse production system made of polyethylene sheets is used to grow capsicum in hilly areas of Tamil Nadu, Himachal Pradesh, Uttar Pradesh, Jharkhand and portions of Gujarat, Maharashtra, and Karnataka. It thrives in the summer months in the highlands and the cooler months on the plains. Greenhouse helps to keep the area warm throughout the chilly season, attracting pollinators and beneficial insects while keeping out unwanted nuisance insects[12]. *Capsicum* species are commonly used in the preparation of pickles, sauces, and condiment foods[13]. *Capsicums* are rich in nutrients such as calcium, iron, potassium, salt, thiamine, riboflavin, niacin and Flavonoid[14]. They also include 88% water, 40 kcal of calories, 2.22 g of protein, 8.9 g of carbs, and 1.56 g of fiber per 100 g[14]. The chemical compounds found in *Capsicum* exhibit remarkable diversity and health-promoting qualities. Compounds such as capsaicinoids and capsaicin shows anticancer properties and provitamin A (carotenoids), which is a potent antioxidant and anti-inflammatory agent[15,16,17]. Fresh chilli peppers are high in vitamin C, making them excellent immune system boosters and healing agents, particularly for cellular damage[16] and Oleoresin has antidiabetic properties[17,18]etc. Chilli is extremely good for the cardiovascular system[18]. It inhibits cholesterol accumulation and lowers platelet aggregation that ultimately lowering the risk of heart attack and strokes[19]. It also reduces hypertension and improves peripheral circulation[19]. As a commercial crop, chilli has consistently been in high demand worldwide because of its nutritional content and health advantages so it is crucial to increase the production of chillies[20]. Due to biotic

and abiotic stress, the amount of chilli produced is still below ideal levels[21,22]. Certain abiotic stress, such as arsenic found in soil due to human activity, anthropogenic and geochemical sources[23] and the use of pesticides containing arsenic to protect against various biotic stress, also cause unfavourable effects, such as the induction of genetic damage in plant cells from indiscriminate use. Arsenic is a non-biodegradable contaminant with a high persistence in ecosystems and the capacity to build up in the food chain, which can cause significant harm to the health of soils, plants, animals, and people at even low concentrations, according to the FAO[24]. The primary effects of arsenic on non-target organisms include cytotoxicity, clastogenicity and genotoxicity[25]. The phytotoxicity of arsenic is significantly influenced by the concentration of the metalloid and the form of arsenic present in the soil.[25]. The current study focuses on comparative karyomorphological investigations of different species of *Capsicum*, which provides genetic information about genetic variants and few species will be treated with heavy metal, i.e., Arsenic, to observe genotoxic effects of arsenic at different concentrations that produce errors in the genetic information system as changes in chromosome shape, chromosome number and spindle disruptions and cytotoxic effects[25].The impact of different concentration of arsenic will also be analyzed at a morphological and biochemical level. The phytoremediation potential of *Capsicum* species against arsenic will also be analyzed[26,27]. It is an effective, economical, and ecologically sustainable way to treat contaminated soils.

PROBLEM TO BE INVESTIGATED

Karyomorphological studies will be conducted on few *Capsicum* species to assess the primary information regarding chromosomes morphology, arrangement and size as well as the impact of arsenic exposure at different doses to find out the chromosomal aberrations and morphological changes in *Capsicum*. Additionally, the chlorophyll content and phytochemical constituents will be estimated in both control plants and those treated with arsenic to evaluate their resistance and sensitive levels. The plant's phytoremediation potential will also be analyzed to determine its efficacy in mitigating arsenic contamination.

OBJECTIVE OF INVESTIGATION

1. To analyze the chromosomal morphology and behavior in different *Capsicum* species.
2. To determine the genotoxic effects of arsenic on *Capsicum* species using chromosomal aberration studies.
3. To evaluate the morphological changes in *Capsicum* plants under varying concentrations of arsenic.
4. To measure and compare chlorophyll content in control and arsenic treated seeds of *Capsicum*.
5. To assess the levels of phytochemicals in *Capsicum* plants exposed to arsenic.
6. To investigate the potential of *Capsicum* species for arsenic uptake and accumulation.

MOTIVATION

The genus *Capsicum* species comprises diploid, self and cross-pollinated species with chromosome numbers 24[3]. *Capsicum* is one of the major vegetable crops grown worldwide for its economic importance and nutritional value. *Capsicum* farming can be a profitable business due to the high commercial benefit and low production costs of the spice. *Capsicum* is a versatile spice that can be used in cooking, beverages, cosmetics and medicines[13]. They are rich in vitamins A and C, minerals such as iron, potassium, magnesium and calcium, which have a health-promoting potential [15,17,27]. *Capsicum* is also used to relieve pain, boost the immune system, and lower cholesterol and fruits are used in ayurveda[21]. *Capsaicin* is used as a food additive and in pharmaceutical applications[13]. it has been found that capsaicin can act as a cancer preventive agent and it is use against various types of cancer[13]. *Capsicum* species have also antidiabetic, antioxidant and antimicrobial properties[27,28,29]. *Capsicum* has rheumatism, stiff joints, bronchitis, chest colds, coughs, headaches, arthritis, heart arrhythmias, and many other properties[30,31]. Apart from all these properties, *Capsicum* can perform phytoremediation, which results in the soil becoming healthier by absorbing heavy metals[26,27].

HYPOTHESIS

Comparative Karyomorphological studies of *Capsicum* species are carried out to determine the similarities and differences in the karyotype, allowing the fundamental set of chromosomes to be identified. The primary goal of study is to evaluate the intervarietal relationship[32].

The selected species will be treated with different concentration of arsenic, revealing the different doses and their efficiency at the chromosomal, morphological, and biochemical levels[33]. The effect of arsenic on chlorophyll concentration and transport of arsenic into different parts of plants, like roots and stems, etc., which may show phytoremediation properties[26,33].

RESEARCH DESIGN AND METHODOLOGY

- **Collection of seed of *Capsicum* species**

  Seed will be collected from authorized seed center or seed bank.

- **Cytological Studies:** For Cytological studies of *Capsicum*, healthy seed will be used. The seed will be soaked in a petri dish containing 110mm Whatman filter paper moistened with water for a period of three to seven days. When the roots have grown a length of 1-2mm, the tip will be excised at the appropriate time and excised roots will be immersed in a 0.002M solution of 8-hydroxyquinoline followed by treatment with Carnoy's fluid (3:1 ethanol/acetic acid v/v). The roots will then be

preserved in 70% alcohol and kept in the refrigerator until needed for slide preparation. Preserved tip will be stained in orcein and temporary slides will be prepared by squash technique and examined under a light microscope[33].

For Karyomorphological studies, the length and the size of chromosome will be studied at the metaphase stage with the help of micrometer and ocular scale under microscope and photographs will be taken. This information will be used to determine absolute length, relative length, angular value, log value, total chromatic index, symmetry index, anaphase index, and telophase index[34].

- **Study of Genotoxicity of arsenic:** Arsenic will be added either as sodium arsenite ($NaAs0_2$) or disodium hydrogen arsenate (Na_2HAs0_4) at the 5 different concentrations of (0, 2, 10, 50, and 100 mg) As kg- 1 in soil. Few species of Capsicum will be grown in controlled and treated soil for analysis of their genotoxic effects on different parts of plants in the M1 and M2 generations[35].

- **Study of Plant morphology:**

  Seed germination - Seeds will be plated on petri plates with moist Whatman filter paper and the germination test will be calculated. The germination test will be calculated by dividing the number of germinating seeds by the total number of seeds plated[33].

  Root Length - The control and treated plants will be removed from their pots, and the roots will be examined carefully. A measuring scale will be used to determine the root length of the Collected plants[36].

  Shoot Length - After removing the control and treated plants from their pots, the shoots will be carefully separated. Then comparative studies of shoot length will be done, and length will be measured with the help of a measuring scale[36].

- **Chlorophyll Estimation:** The 80% acetone solvent method, which is used to estimate chlorophyll levels, 0.25 g of leaf material is grinding in 2 ml of 80% acetone with sand, 0.1%, or 0.1 $CaCO_3$ to inhibit chlorophyllase activity. A spectrophotometer will be used to measure absorbency after the samples have been filtered through filter papers till the final volume reaches 25 ml[37].

- **Estimation of phytochemical:** The leaves of *Capsicum* will be sun-dried for 72 hours, then weighed. Fifty grams of the leaves will be macerated in 96% ethanol with a pestle and mortar. An exhort extraction machine will be used to filter and evaporate the extract to dryness using a rotary evaporator set at 45^0C to a preset weight. Residue yields will be measured, and a portion will be used for phytochemical screening. Liquid chromatography mass spectrometry (LC-MS) will be used for phytochemical screening[33].

- **Study of phytoremediation:** The samples will be dried in an oven at 70°C for 24 hours, and ash will be created in a muffle furnace at 550°C for 20 hours. Then it will be treated with 17.5% (v/v) H_2O_2 and 31% (m/v) HNO_3 at 70°C for two hours before being given distilled water. The sample will be taken in an atomic absorption spectrophotometer to estimate arsenic concentration[36]**.**

TOOLS TO BE USED IN THE COLLECTION OF DATA

Plant materials, Petri dish, measuring cylinder, Conical flask, Beaker, Microslides, Coverslip, Forceps Needle, Sprite lamp, Filter paper, Match box, measuring scale, Various chemicals, pH meter, Thermo-mixer, Weighing machine, Stage micrometer, Ocular scale, Microscope, Books, Journal, Computer etc.

SIGNIFICANCE OF THE STUDY

- Karyomorphological studies are performed for the identification and characterization of morphology of chromosomes of different species of *Capsicum*[32].
- Comparative studies of the karyotype of different species of *Capsicum* can help to understand the evolutionary trends in *Capsicum*, such as the origin of cultivated taxa and also determine similarities and differences in their karyotypes[34].
- The impacts of various arsenic concentrations in different parts of *Capsicum* will be significant for understanding the genetic effects of metals on plant systems and exploring plant tolerance to metals[36].
- As a phytoremediation technique, *Capsicum* species aids in the removal of dangerous heavy metals from contaminated soil. The technique is eco-friendly[36,42].

ITS RELEVANCE TO THE PRESENT DAY PROBLEM AND NEED OF THE SOCIETY

In comparative studies of the karyomorphological of different species of *Capsicum*, we can interpret relationships between different species and their genetic variations[32]. It can also aid to understand the evolutionary trends of *Capsicum*, such as the origin of cultivated taxa. Arsenic pollution is now a major environmental concern affecting many locations across the world. It poses a significant threat to agricultural production, food safety and human health[25]. The rising levels of arsenic in soil and water as a result of industrial operations and poor waste management have led to the necessity of finding effective ways to mitigate this problem. The study of arsenic stress on *Capsicum* species provides insights into how these plants respond at the cellular, morphological and biochemical levels, which is crucial for developing strategies to cultivate crops in arsenic-contaminated areas[36]. The study is crucial to society because it tackles the pressing issue of enhancing food security in regions where arsenic pollution is a problem. *Capsicum* species, which are widely utilized in culinary and medicinal uses, constitute a staple crop in many nations. Understanding their

phytoremediation capacity can aid in the cleanup of arsenic-contaminated soils, providing an environmentally beneficial and sustainable solution to the arsenic problem[36,42]. This could reduce arsenic levels in food crops, lowering the health concerns linked with arsenic ingestion.

CONTRIBUTION TO THE EXISTING KNOWLEDGE

- Karyomorphological comparisons of various *Capsicum* species provide an understanding of the differences in evolutionary patterns and genetic variants [38,39, 40].
- Karyomorphological and cytogenetic data can be used for species identification, phylogenetic reconstruction, and solve practical difficulties[39,40,41].
- This study greatly adds to the existing body of knowledge by giving detailed information on the karyomorphological, morphological, and biochemical responses of *Capsicum* species to arsenic stress[36].
- These results may help us better understand the cellular and molecular mechanisms of plant tolerance, which could lead to genetic advancements in other crops, including *Capsicum* species[36,42].
- Furthermore, identifying *Capsicum* species with strong phytoremediation capability might help guide breeding programmers and agricultural methods aimed at generating crops that can flourish in arsenic-polluted environments[42].

FUTURE WORK

- The cytological function in the genus is still inadequate, thus further cytogenetics research will be required to properly comprehend the links within and between species.
- Future study should focus on finding the genes in *Capsicum* that are involved in arsenic uptake, as well as developing arsenic tolerant plants utilizing genomic selection methods.
- More research and strategy development are required to keep arsenic out of the food chain.
- To gain more insight into the processes governing plants tolerance and accumulation of heavy metals.
- To determine technique of genetic engineering and molecular science research can improve the impact of phytoremediation.

REFERENCES

1. Karim, K. M., Rafii, M. Y., Misran, A. B., Ismail, M. F. B., Harun, A. R., Khan, M. M. H. and Chowdhury, M. F. N. (2021). Current and Prospective Strategies in the Varietal Improvement of Chilli (*Capsicum annuum* L.) Specially Heterosis Breeding. *Agronomy.* 11 (11): 2217.

2. Tanksley, S. D. (1984). High rates of cross-pollination in chile pepper. *HortScience.* 19 (4): 580-582.

3. Mongkolporn, O. and Taylor, P. W. (2011). *capsicum* Wild Crop Relatives: Genomic and Breeding Resources: Vegetables *Legume Crops and Forage.* 43-57.

4. Kumar, S., Kumar, R. and Singh, J. (2006). Cayenne/American pepper (*Capsicum* species). In: Peter KV (ed) *Handbook of herbs and spices*, vol 3. Woodhead Publishing. Cambridge, UK, pp 299–312.

5. Villa-Rivera, M. G. and Ochoa-Alejo, N. (2021). Transcriptional Regulation of Ripening in Chili Pepper Fruits (*Capsicum* spp.). *International Journal of Molecular Sciences* 22 (22): 12151.

6. Cheema, S. K. and Pant, M. R. (2013). Karyotype analysis of seven cultivated varieties of *Capsicum annuum* L. *Caryologia.* 66 (1): 70-75.

7. Perez, T. H., Garcia, M. D. R. G., Valverde, M. E. and Lopez, P. (2020). *Capsicum annuum* (hot pepper) - An ancient Latin-American crop with outstanding bioactive compounds and nutraceutical potential: A review. *Comprehensive Reviews in Food Science and Food Safety*. 19 (6): 2972-2993.

8. Shah, N. C. (2023). Origin, introduction, and cultural history of *capsicum* in India. *Indian Journal of History of Science.* 58 (4): 312-319.

9. FAO, (2023). FAOSTAT Database Food and Agriculture Organization of the United Nations, Rome. Available from :https\\faostat.fao.org.

10. Sunil, C., Kadam, P. V., Kanavi, G. B. J., Onte, S., Salimath, S. B., Jeevan, H. R., Mallikarjuna, H. B., Chandra, M. S. and Seema, N. U. (2024). Comparative assessment of nano nitrogen and nano zinc nutrition on growth, yield and profitability of chilli (*Capsicum annuum*. L). *Journal of Plant Nutrition*. 1-15.

11. Mishra, B. P. (2024). A study on problems and suggestions of chilli growers in Andhra Pradesh, India. *Plant Science Today.* 11(2): 620-625.

12. Singh, D. (2012). Production and Management of *Capsicum* in Greenhouse Center of Advanced Faculty Training in Plant Pathology. *The Indian Journal of Agricultural Sciences. 8(1):* 220-223.

13. Ananthan, R., Subash, K. and Longvah, T. (2014). Assessment of nutrient composition and capsaicinoid content of some red chilies. *International Conference on Food and Nutrition Technology* 72: 1–4.

14. Karatas, A., and Buyukdinc, D. T. (2024). Evaluation of the Fruit Characteristics of Pepper (*Capsicum annuum* L.) Genotypes Collected from the Eastern Black Sea Region of Turkiye from the Eastern Black. *Journal of Anatolian Environmental and Animal sciences.* Vol 9 (3)*: 485-492.*

15. Mittal, M., Siddiqui, M. R., Tran, K., Reddy, S. P., Malik, A. B. (2014). Reactive oxygen species in inflammation and tissue injury. *Antioxid. Redox Signal*.20, 1126–1167.

16. Howard, L. R., Talcott, S. T. and Brenes, C. H. (2000). ACS Publications Changes in Phytochemical and Antioxidant Activity of Selected Pepper Cultivars (*Capsicum* Species) As Influenced by Maturity *Journal of agricultural Food chemical*. 48, 1713−1720.

17. Aune, D., Keum, N., Giovannucci, E., Fadnes, L. T., Boffetta, Greenwood, P., Tonstad, D. C., Vatten, S., Riboli, L. J. and Norat, E. (2018). Dietary intake and blood concentrations of antioxidants and the

risk of cardiovascular disease, total cancer, and all-cause mortality: A systematic review and dose-response meta-analysis of prospective studies. *The American Journal of Clinical Nutrition*. 108, 1069–1091.

18. Mohammed, A., Koorbanally, N. A. and Islam M. S., (2017). Anti-diabetic effect of *Capsicum annuum* L. fruit acetone fraction in a type 2 diabetes model of rats. *Acta Poloniae Pharmaceutica Drug Research*. 74(6): 1767–1779.

19. Gurnani, N., Gupta, M., Shrivastava, R., Mehta, D. (2016). Effect of extraction methods on yield, phytochemical constituents, antibacterial and antifungal activity of *Capsicum frutescens* L. Indian *Journal of Natural Products and Resources*. 7(1): 32-39.

20. Reddy, K. M., Ponam, N., Barik, S., Reddy, V. R., Saha, K., Reddy, D. C. L. and Sujatha, K. (2023). Chillies and *Capsicums* in India, 75 Years of Research and Development, *Handbook of Spices in India*. 2033-2084.

21. Parisi, M., Alioto, D. and Tripodi, P. (2020). Overview of Biotic Stresses in Pepper (*Capsicum* spp.): Sources of Genetic Resistance, Molecular Breeding and Genomic. *International Journal of Molecular Sciences.* 21 (7): 2587.

22. Reddy, K. M., Shivashankara, K. S., Geetha, G. A. and Pavitra, K. C. (2016). *Capsicum* (Hot Pepper and Bell Pepper). *Abiotic stress physiology of horticultural crops*. 151-166.

23. Panda, S. K., Upadhyay, R.K., Nath S. (2010). Arsenic stress in plants. Wiley Online Library. *Journal of Agronomy and Crop Science.* 196(3): 161-174.

24. Rosas-Castor, J. M., Guzman-Mar, j. L., Hernandez-Ramirez, A., MT Garza-Gonzalez, M. T., Hinojosa-Reyes, L. (2014). Arsenic accumulation in maize crop (Zea mays): a review Science of the Total Environment 488, 176-187.

25. Patra, M., Bhowmik, N., Bandopadhyay, B. and Sharma A. (2004) Comparison of mercury, lead and arsenic with respect to genotoxic effects on plant systems and the development of genetic tolerance. *Environmental and Experimental Botany.* 52: 199–223.

26. Chen, L., Cui, Z. X. and Wang, D. (2020). Variations in Cd and Pb - Accumulations of Hot Pepper (*Capsicum annuum* L.) Cultivars for Screening Pollution-and Nitrate-Safe Cultivars. *Polish Journal of Environmental Studies.* 29 (4):2597-2607.

27. Howard, L. R., Talcott, S. T., Brenes, C. H. and Villalon, B. (2000). Changes in phyto-chemical and antioxidant activity of selected pepper cultivars (*Capsicum* spe-cies) as influenced by maturity. *Journal of Agricultural and Food Chemistry*. 48: 1713-1720.

28. Kim, W. R., Kim, E. O., Kang, K., Oidovsambuu, S., Jung, S. H., Kim, B. S., Nho, C. W. and Um B. H. (2014). Antioxidant Activity of Phenolics in Leaves of Three Red Pepper (*Capsicum annuum*) Cultivars. *Journal of Agricultural and Food Chemistry*. 62: 850–859.

29. Nevry, R. K., Kouassi, K. C., Nanga, Z. Y., Koussemon, M. and Loukou, G. Y. (2012). Antibacterial activity of two bell pepper extracts: *Capsicum annuum* L. and *Capsicum* frutescens, *International Journal of Food Properties*. 15(5): 961-971.

30. Blanc, P., Liu, D., Juarez, C., Boushey, H. A. (1991). Cough in hot pepper workers. *Chest.* 99 (1): 27–32.

31. Saleh, B. K. and Omer, A. (2018). BJMFPT Teweldemedhin Medicinal uses and health benefits of chili pepper (*Capsicum* spp.): a review *MOJ Food Process Technol.* 6 (4): 325-328.

32. Dixit P. D. (1931). A cytological study of *Capsicum annuum*. *Indian Journal of Agricultural Science*. 1(4): 419 – 433.

33. Waha, C., Okoli, B. E. and Wosu, N. L. E. (2014). Morphological, anatomical, cytological and phytochemical studies on *Capsicum annuum* Linn. (Solanaceae) Department of Plant Science and Biotechnology, University of Port Harcourt, Chob, Nigeria Pelagia Research Library *European Journal of Experimental Biology*. 4(1): 464-471.

34. Lakra, S. G., and Kumar, K. (2020). Karyomorphology of Three Succulent Species *Gasteria batesian*, *Haworthia limifolia* Var. Longiana and *Aloe jucunda* (Family Asphodelaceae). *The Journal of Indian Botanical Society*. 99 (3&4): 166-171.

35. Das, I., Ghosh, K., Das, D. K., Sanyal, S. K. (2013). Assessment of arsenic toxicity in rice plants in areas of West Bengal Chemical Speciation & Bioavailability. 25 (3), 201-208.

36. Nawaz, M., Shahzadi, E., Yaseen, A. and Khalid, M. R. (2024). Selenium improved arsenic toxicity tolerance in two bell pepper (*Capsicum annuum* L.) varieties by modulating growth, ion uptake, photosynthesis, and antioxidant Profile. *BMC Plant Biology*. 24,799.

37. Ali, K. A., Noraldeen, S. S., and Yaseen, A. A. (2021). An evaluation study for chlorophyll estimation techniques. *Sarhad Journal of Agriculture.* 37(4):1458-1465.

38. Phulari, S. S. and Dixit, G. B. (1996). Cytological studies in *Capsicum*. I. Karyomorphological studies in parents and hybrids of *Capsicum annuum* and *C. frutescens*. *Advances in Plant Sciences*. 9 (2): 111-119.

39. Firdaus, S., and Kumar, K. (2021). Comparative Karyomorphological studies of two species of Crinum. International Journal of advanced research. 9 (2):787-792.

40. Rani, N., Kumar, K. (2011). Karyomorphological studies in the genus Catharanthus. *Indian Journal of Genetics and Plant Breeding.* 71 (01): 55-60.

41. Parveen, R., Kumar K. (2013). Comparative karyomorphological analysis on two varieties of Stevia rebaudiana Bertoni.Journal article: Advances in Plant Sciences. 26 (2): 327-329.

42. Saadony, M. T., Sayed M. D., Khaled, A. T., Synan F. A., Saad, A. M. (2024). Exploiting the role of plant growth promoting rhizobacteria in reducing heavy metal toxicity of pepper (*Capsicum annuum* L.). *Environmental Science and Pollution Research* 31 (18): 27465-27484.